

IMPACT OF PHYSIOLOGICAL AND PSYCHOLOGICAL FACTORS ON
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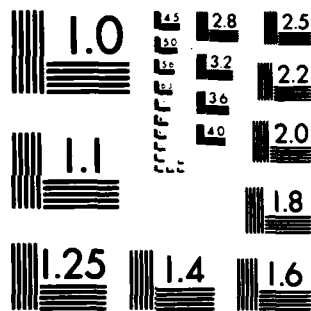
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PHYSIOLOGICAL AND PSYCHOLOGICAL FACTORS
IN PERFORMANCE IN A MIDDLE DISTANCE RUN

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REPORT NO. 80-30

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IMPACT OF PHYSIOLOGICAL AND PSYCHOLOGICAL FACTORS ON PERFORMANCE IN
A MIDDLE DISTANCE RUN

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ABSTRACT

✓ The predictive utility of using psychological variables to explain performance differences not accounted for by differences in physiological capacity was explored. It was hypothesized that psychological variables would affect performance directly as well as by modifying the relationship between physical capacity and performance. $\dot{V}O_2$ max, attraction to physical activity, estimation of physical ability, and the psychological defenses of reversal and turning against self were employed to predict performance by Navy recruits in a 3.62 km (2.25-mile) run. A stepwise multiple regression procedure entered $\dot{V}O_2$ max as the first predictor of performance followed by the psychological variables and then the interactions between $\dot{V}O_2$ max and the psychological variables. $\dot{V}O_2$ max accounted for 52.4% of the variance in performance ($p < .001$). Direct effects of reversal (9.0%, $p < .001$) and estimation of physical ability (4.4%, $p < .05$) were significant. Significant interactions were found for $\dot{V}O_2$ max with estimation of physical ability (7.7%, $p < .01$), turning against self (2.6%, $p < .05$), and reversal (2.8%, $p < .05$). → The evidence indicates that psychological variables should be included in models of performance for physical tasks. Such models will probably incorporate situation-specific psychological variables (e.g., elements of situational motivation) to fully understand the psychological dynamics connecting general personality measures and performance.



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Performance in athletics depends on a combination of physiological endowments and psychological set (1, pp. 4-7). Although physiological and psychological differences between athletes in different sports and between athletes and nonathletes have been described (1,8,13,26), little is known about the interplay of physiological and psychological variables in actual athletic performance. This study explores one aspect of that interplay, the relation of selected psychological and physiological attributes to running performance.

Several studies have found the maximal rate of oxygen consumption ($\dot{V}O_2$ max) to be related to running performance. In 1967, Costill (4) reported a correlation of -0.83 between $\dot{V}O_2$ max and running time in a sample of college cross-country runners completing a 4.7-mile course. Other studies have replicated the negative correlation (6,21) and shown that the correlation is affected by distance (Dr. A. A. Sucec, unpublished observations) and heterogeneity of the sample, e.g., $r = -0.83$ in Costill's (4) cross-country runners and $r = -.21$ in a group of elite marathoners (5).

Despite the general consistency of the findings relating $\dot{V}O_2$ max and running performance, even the highest of the correlations account for only 75% of the variance in performance. Psychological factors may account for some of the remaining variance, but relatively little is known about their influence.

Attitudes towards physical activity influence motivation to perform and may thereby influence performance in activity (16, pp. 127-143). In 1974, Sonstroem (24) measured subjective estimation of ability (EST) and attraction to physical activity (ATTR). Both of these attitudinal scales were significantly related to the time required to complete a 600-yard run ($r = -.46$ for

EST and $r = -.45$ for ATTR) (24). However, in this study EST and ATTR were also correlated with other fitness parameters which might explain the association to performance. No analysis was performed to determine whether the attitudinal measures were independent predictors of performance, so their contribution is equivocal.

Attitudinal variables are not the only psychological attributes that may be related to performance. Psychological defenses are another possibility. Defenses are motivated biases in perception which develop from the need to resolve conflicts (cf., 15). Physical exertion may involve a variety of conflicts including those between pain and satisfaction with performance and the "thrill of victory" versus "the agony of defeat." The type of defense an individual employs may determine how such conflicts are resolved and thereby alter performance. For example, the repression of pain or fear of defeat may facilitate performance.

The effect of psychological factors on performance is probably complex. Attitudinal and personality variables may have some simple direct effects on performance independent of ability (e.g., lower attraction may generally produce poorer performance), but some effects may occur because psychological variables affect utilization of physical abilities. If so, the relationship between ability and performance will be contingent on the individual's psychological set. This observation is consistent with anecdotal observations concerning athletes, but there appears to have been no previous direct test of the general hypothesis. If a contingency does exist, performance will not depend on a simple summation of the effects of physiological and psychological variables. Instead there will be interactions between the two that figure significantly in predicting performance.

In this study we test two hypotheses: 1) that both physiological and

psychological variables combine to predict performance, and 2) that physiological and psychological variables predict performance not only as simple main effects but also interactively.

METHODS

Sample

The participants in this study were 48 U. S. Navy male recruits in their final week of training at the Naval Training Center in San Diego, California. As a part of their final physical fitness test, they are required to run 3.62 km (2.25 miles) in 18 minutes or less to graduate from basic training. Performance on this run was used as our criterion. $\dot{V}O_2$ max was used as our physiological predictor of running capability, and we used two attitudinal and two defense scales as our psychological predictors. Participants were volunteers who consented to participate after the study was explained to them. Forty-four were white and four were black. Their average age was 19.1 years (S.D. = 2.15). Most were between 17 and 19 years of age, but one was 30 years old. Their average education level was 11.9 years (S.D. = 0.61, N = 35).

Procedure

Data was collected on two consecutive days. On the first day, volunteers came to the laboratory. They were given information about the study, and consent to participate was obtained. Descriptive anthropometric and physiological data were collected, and the participants filled out questionnaires. On the second day, the participants ran the 3.62 km.

Anthropometric Measures

Anthropometric measures included height in stocking feet, weight in shorts and socks, and four skinfold thicknesses (biceps, triceps, subscapular, and suprailiac) measured to the nearest 0.1 mm with Harpenden skinfold

calipers. Percent body fat was estimated from the total skinfold thickness using the body density equations of Durnin and Womersley (7) and the density to percent body fat conversion of Siri (23).

Maximum Oxygen Consumption Rate ($\dot{V}O_2$ Max)

$\dot{V}O_2$ max was determined from open-circuit spirometry measures gathered during a single walk/run bout on a motor-driven treadmill. Participants began walking at 4.02 km/hr, 0% grade and were allowed to warm up under these conditions for 4 minutes. At 4 minutes, the speed was increased to 4.83 km/hr. At 5 minutes, the grade was increased to 3%. At 6 minutes, the grade was increased to 6%. At 7 minutes, the speed was increased to 5.63 km/hr. At 8 minutes, the grade was increased to 9%. Thereafter, the speed was increased 0.8 km/hr each minute until $\dot{V}O_2$ max was reached or the participant indicated he could no longer continue.

Open-circuit spirometry measures were gathered using a system composed of an O_2 analyzer (Applied Electrochemistry, Model S3-A), a CO_2 analyzer (Beckman Instruments, Model LB-2), a spirometer (K. L. Engineering, Pneumoscans, Model S-300) and an air temperature thermometer (Yellow Springs Instruments, Model 43T-A), all interfaced with a programmable desk-top calculator (Hewlett-Packard, Model 9825A). The subjects breathed through a one-way respiratory valve (Ewald Koegel Co.). Expired gas was continuously sampled from a mixing chamber and the CO_2 and O_2 composition determined.

The rate of oxygen consumption ($\dot{V}O_2$) and other spirometry values were calculated, printed out, and recorded on magnetic tape at 15-second intervals. $\dot{V}O_2$ max was considered to have been reached when $\dot{V}O_2$ did not increase in the 1-minute following an increase in work load. The $\dot{V}O_2$ max value was taken to be the highest computed 1-minute average of the $\dot{V}O_2$ values recorded during the test.

Questionnaires

Sonstroem's Physical Estimation and Attraction Scales (PEAS) (24) provided measures of EST and ATTR. The PEAS consists of 100 true-false items which were read to the participants who marked their responses on computer scoring forms.

Gleser and Ihilevich's (10) Defense Mechanisms Inventory (DMI) provided measures of turning against self (TAS) and reversal (REV). TAS reflects defenses that direct aggressive behavior inwards (e.g., any masochistic or self-belittling behavior). REV assesses defenses which neutralize frustration or actually reverse the response to it (e.g., denial, repression, reaction formation). The DMI measures five clusters of defenses through responses to ten brief stories describing conflict situations. Respondents indicate their most and least likely response to each situation from among five possibilities each for actual behavior, fantasy behavior, thought, and affect. Only two of the five DMI scales were used because the scales are typically highly intercorrelated (e.g., 10,11,12). TAS was chosen because it was the most independent of the scales. REV was chosen to represent the remaining four scales because its correlation with each of the others equaled approximately 1.00 following correction for attenuation due to measurement error (cf., 18, pp. 203-204, 217-220) and because it was easy to conceptualize how this defense cluster might relate to performance (see above).

Performance

Participants typically ran in groups of four or five recruits who all started at the same time. The run was conducted on a 402.3 m track and lap number and cumulative time were called out as each person passed the starting point. Each individual was allowed to run at his own pace, but knew he must

complete the run in 18 minutes or less to graduate from basic training. Times were taken by hand-held electronic stopwatches and performance is reported in terms of total run time.

Analysis Procedures

The Statistical Package for the Social Sciences (SPSS) was used to perform the analysis (17). The analyses consist of ordinary correlation procedures and multiple regression procedures described below.

Multiple regression was used to determine the combined effects of predictors on performance. Running time was predicted by $\dot{V}O_2$ max and the self-report psychological variables. Interaction terms were developed by multiplying $\dot{V}O_2$ max scores by psychological scores (cf., 3). The scores were standardized prior to computing the cross-product to eliminate effects of differences in raw score variances.

Using stepwise regression procedures, variables were entered into the multiple regression in three stages: (1) $\dot{V}O_2$ max was entered as a predictor; (2) psychological variables were added one at a time until all had been added to the regression; and (3) the interactions were added one at a time to the predictors from the first two stages. Interactions were added only until the next one to enter would not be significant at the $p < .10$ level. A final multiple regression was computed eliminating those psychological variables which were not significant ($p < .10$) predictors of performance.

RESULTS

The means and standard deviations of the physical and psychological parameters for this sample of recruits are given in Table 1. The physical and fitness characteristics were essentially the same as those reported for Army trainees at the end of basic training (14). The Navy recruits had a high level of aerobic fitness compared to the general population (2, p. 15).

The recruits showed slightly but significantly lower EST (21.2 vs. 23.9, $p < 0.05$) scores and essentially the same ATTR scores as the Army trainees (14). Compared to a reference sample of college sophomores (10), the recruits showed higher levels of REV (40.8 vs. 36.6, $p < .01$), but were not significantly different on TAS.

Running Performance

On the average, these recruits completed the 3.62 km run in 17.2 min (S.D. = 2.3 min). The fastest man completed the run in 13.71 min, the slowest man in 25.87 min. Eight recruits in our sample failed to complete the run in the required 18 min.

[Insert Table 1 about here]

Prediction of Performance

Table 2 gives the intercorrelation matrix for the variables in this study. The results of the multiple regression analysis to predict performance are given in Table 3. As described in the methods, $\dot{V}O_2$ max was the

[Insert Table 2 about here]

first variable entered into the equation and this accounted for 52.4% of the variance in run time. The main effects for psychological variables were entered next with the first variable, REV, increasing the accuracy of prediction by 9.0% and the second, ATTR, accounting for another 4.4% for a total of 13.4%. Three interactions between $\dot{V}O_2$ max and psychological variables added significantly to the prediction of run time. The interaction with EST

[Insert Table 3 about here]

increased the variance accounted for by 7.7%, followed by interactions with

TAS (2.6%) and REV (2.8%) for a total of 13.1% due to the addition of the interaction terms.

A graphic representation of the interactive effects of REV, EST, and TAS upon the relationship between $\dot{V}O_2$ max and 3.62 km running time is given in Figure 1. On each axis pair, the lines shown represent the relationship between $\dot{V}O_2$ max and run time for two levels of the psychological variable (REV, EST, or TAS). All other parameters are held constant. The lines marked "LOW" show the $\dot{V}O_2$ max - running time relationship when the psychological parameter is set one standard deviation below its mean. The lines marked "HIGH" show the regression when the psychological parameter is set one standard deviation above its mean. In each case, the "HIGH" scores were associated with a flatter slope for the functional relationship between $\dot{V}O_2$ max and run time. Therefore, a given difference in $\dot{V}O_2$ max levels produces a lesser difference in performance when the psychological scores are higher.

[Insert Figure 1 about here]

As can be seen in Table 3, 79% of the total variance is accounted for by the regression equation. The sample size was too small to allow the sample to be subdivided for cross-validation of this equation. Therefore, the square of the correlation coefficient which would be expected upon cross-validation was estimated using the formula of Lord and Nicholson (22) following the suggestions of Schmitt et. al. (22). The value of this "shrunk" R^2 is .716 and is included in Table 3 in parenthesis.

DISCUSSION

The results of this study provided general support for our hypotheses. Accurate prediction of running performance required consideration of both physiological and psychological attributes. Furthermore, the two types of

predictors were not simply additive as there was evidence that interactions between physiological and psychological factors influenced performance.

The results concerning prediction of performance parallel findings from other studies when direct comparisons are possible. $\dot{V}O_2$ max is a strong predictor of running time. The correlation is among the highest reported to date, but still accounts for only 52.4% of the variance in performance. While this percentage may be influenced by the length of the run, the population sampled, and other factors, the important point is that much of the variance in performance is unexplained.

The present results also replicated Sonstroem's (24) finding that EST and ATTR were associated with faster running times. The values for the simple correlations (see Table 2) are quite close to the $r = -.46$ and $r = -.45$ reported by Sonstroem (24). Partial correlations controlling for $\dot{V}O_2$ max were $r = -.33$ ($p < .05$) for EST and $r = -.34$ ($p < .05$) for ATTR, so these associations were not entirely due to the correlation of attitudes to $\dot{V}O_2$ max. Furthermore, ATTR remained a significant predictor of performance in the multiple regression analyses (see Table 3) that controlled for both $\dot{V}O_2$ max and other psychological predictors of performance. These observations imply a direct effect of motivationally relevant attitudes on performance (see also 16,24,25).

It should be added, the nature of this particular task would be expected to reveal the effects of motivationally relevant factors. The recruits were only required to complete the run in 18 minutes. This level of performance is easily achieved by over 90% of the recruits going through training (CDR Richard White, Director of Technical Training, Recruit Training Command, San Diego, personal communication). Performance above the 18-minute mark must in part represent motivation beyond merely meeting the fitness standard.

These motivational factors were not the only psychological variables that influenced performance. The single strongest psychological predictor of performance was REV, a measure of psychological defense. The association between REV and better performance suggests that the ability to suppress or repress pain can improve performance. These psychological defense concepts are very similar to Petrie's (19) "reduction of sensory input" which Ryan (20) found was more likely in people involved in athletics than in those who were not athletically active. Ryan (20) also found that "reduction of sensory input" was particularly pronounced in those who engaged in contact sports. Combining the present findings with Ryan's (20), the ability to minimize perceptions of pain appears to be an important psychological factor in physical activity. This psychological attribute may be capable of both explaining some aspects of self-selection for physical activity and predicting performance when unselected individuals are required to perform physical tasks. Furthermore, this psychological attribute appears to operate independently of motivational factors such as those measured by Sonstroem's (24) scales.

As hypothesized, psychological factors modified the relationship between $\dot{V}O_2$ max and performance (see Figure 1). These findings are consistent with the commonly held belief that psychological and physiological factors interact to determine performance. However, interactions can be difficult to replicate and additional study is needed to confirm the present findings. Should the findings replicate, additional research will be needed to understand the details of the psychological processes connecting personality to performance in a particular setting. For example, it seems likely that general personality variables such as REV, TAS, and EST affect performance indirectly through their impact on situational variables such as performance expectations, esti-

mation of effort requirements for performance, and subjective utility of performing well.

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TABLE 1.
PHYSICAL AND PSYCHOLOGICAL CHARACTERISTICS
OF STUDY PARTICIPANTS

	Mean
PHYSICAL CHARACTERISTICS	
Age (Years)	19.1 \pm 2.15
Height (cm)	175.5 \pm 7.37
Weight (kg)	72.6 \pm 10.1
% Body Fat	12.35 \pm 3.49
PHYSICAL FITNESS	
$\dot{V}O_2$ max (l/min)	3.85 \pm 0.55
$\dot{V}O_2$ max (ml/kg min)	53.05 \pm 6.01
PSYCHOLOGICAL VARIABLES	
Estimation of Physical Activity	21.2 \pm 7.9
Attraction of Physical Activity	36.6 \pm 10.3
Turning Against Self	36.6 \pm 5.7
Reversal	40.8 \pm 7.4

Note: Values shown are means \pm S.D. N = 48 except for % Body Fat where N = 47 and $\dot{V}O_2$ max where N = 45.

TABLE 2.
INTERCORRELATIONS: DEPENDENT AND INDEPENDENT VARIABLES

	REV	TAS	EST	ATTR	VO ₂ max	Run Time
Reversal (REV)	—					
• Turning Against Self (TAS)	-.01	—				
Physical Estimation (EST)	.36*	-.23	—			
Physical Attraction (ATTR)	.25	-.03	.61*	—		
VO ₂ max	.23	.03	.44*	.45*	—	
Run Time	-.38*	.08	-.56*	-.55*	.73*	—

*p < 0.05

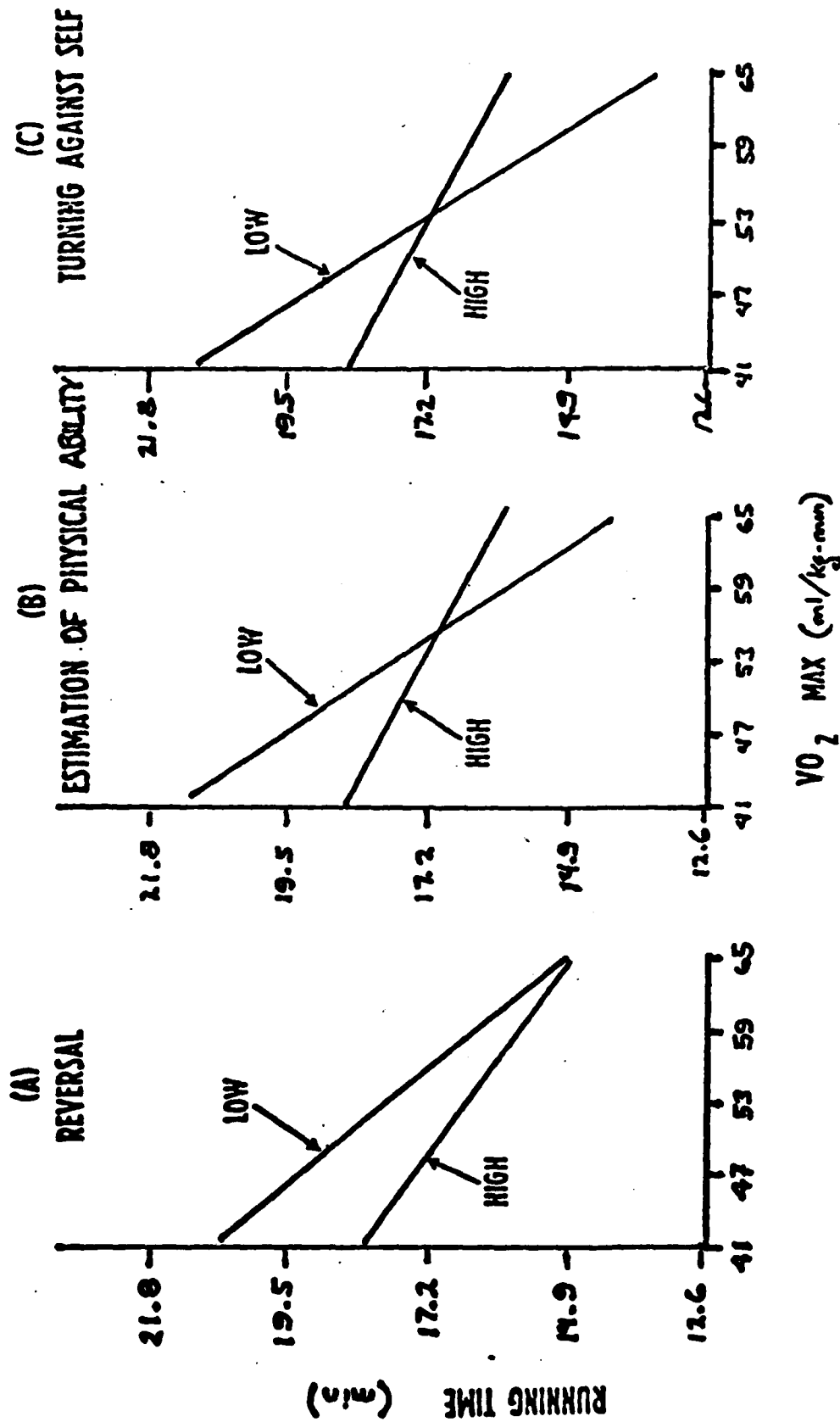
TABLE 3.

REGRESSION EQUATIONS TO PREDICT PERFORMANCE

Dependent Variable	Predictor	B	F	R	R ²
Run Time	$\dot{V}O_2$ max	-.552	41.86	.724	.524
	Reversal	-.288	14.27	.784	.614
	Attraction	-.233	5.27	.811	.658
	$\dot{V}O_2$ max x Estimation	.256	8.49	.857	.735
	$\dot{V}O_2$ max x Turning Against Self	.223	5.76	.873	.761
	$\dot{V}O_2$ max x Reversal	.176	4.88	.888	.789 (.716)*

B = normalized regression coefficient; F = F ratio for testing significance of the regression coefficient; R = multiple correlation coefficient; R² = square of the multiple correlation coefficient (= fraction of variance accounted for by the regression equation).

* estimate of the square of the multiple correlation coefficient expected upon cross-validation (see text).



NOTE: The figure shows the functional relationship between running time and VO_2 max for fixed levels of the indicated psychological variables. The line marked "HIGH" describes the functional relationship when the psychological attribute is fixed at 1 standard deviation above the mean and this value is substituted into the regression equation described in Table 3. The line marked "LOW" is the same relationship when the psychological attribute is fixed 1 standard deviation below the mean. The illustrated relationships indicate the associations that exist holding constant all other predictors of running time except the specific psychological attribute and VO_2 max.

Fig. 1: Representation of Significant Interactions between Psychological Attributes and VO_2 Max as Predictors of Performance.

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20. Abstract (continued)

Navy recruits in a 2.25-mile run. A stepwise multiple regression procedure entered $\dot{V}O_2$ max as the first predictor of performance followed by the psychological variables and then the interactions between $\dot{V}O_2$ max and the psychological variables. $\dot{V}O_2$ max accounted for 52.4 percent of the variance in performance ($p < .001$). Direct effects of reversal (9.0 percent, $p < .001$) and estimation of physical ability (4.4 percent, $p < .05$) were significant. Significant interactions were found for $\dot{V}O_2$ max with estimation of physical ability (7.7 percent, $p < .01$), turning against self (2.6 percent, $p < .05$), and reversal (2.8 percent, $p < .05$). The evidence indicates that psychological variables should be included in models of performance for physical tasks. Such models will probably incorporate situation-specific psychological variables (e.g., elements of situational motivation) to fully understand the psychological dynamics connecting general personality measures and performance.

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